E0089

We claim:

1. A method for reducing diffusion of dopant ions from a doped dielectric layer into a metal layer, comprising:

(a) depositing on said metal layer, a diffusion barrier; and then

(b) depositing a layer of doped dielectric material on said diffusion barrier.

2. The method of claim 1, wherein said diffusion barrier is a layer of metal nitride.

3. The method of claim 1, wherein said diffusion barrier is a layer of metal oxynitride.

4. The method of claim 2, wherein said layer of metal nitride has a thickness in the range of about 10 Å to about 1000 Å.

5. The method of claim 2, wherein said layer of metal nitride has a thickness in the range of about 50 Å to about 350 Å.

6. The method of claim 2, wherein said layer of metal nitride has a thickness of about 100 Å.

7. The method of claim 2, wherein said metal nitride is formed using a nitrogen rich radiofrequency (rf) plasma.

8. The method of claim 7, wherein radiofrequency plasma is formed using hydrogen and nitrogen gases having a ratio in the range of about 0.1:1 to about 4:1.

9. The method of claim 7, wherein radiofrequency plasma is formed using hydrogen and nitrogen gases having a ratio in the range of about 0.5:1 to about 2:1.

10. The method of claim 7, wherein radiofrequency plasma is formed using hydrogen and nitrogen gases having a ratio of about 3:2.

11. The method of claim 7, wherein the rf plasma power is in the range of about 100 Watts per 8 inch wafer to about 1000 Watts per 8 inch diameter wafer.

12. The method of claim 7, wherein the rf plasma power is in the range of about 400 Watts per 8 inch wafer to about 800 Watts per 8 inch diameter wafer.

E0089

11. The method of claim 5, wherein the rf plasma power is about 750 Watts per 8 inch wafer.

13. The method of claim 7, wherein the rf plasma is generated in the presence of a noble gas.

14. The method of claim 13, wherein said noble gas is selected from the group consisting of helium, neon, argon, krypton and xenon.

15. The method of claim 7, wherein the pressure in the plasma chamber is in the range of about 100 milliTorr to about 50 Torr.

16. The method of claim 7, wherein the pressure in the plasma chamber is in the range of about 1 Torr to about 10 Torr.

17. The method of claim 7, wherein the pressure in the plasma chamber is about 4 Torr.

~~18~~ 19. The method of claim 1, wherein the step of depositing a layer of doped dielectric material is carried out at a deposition temperature in the range of about 200° C to about 450° C.

~~19~~ 20. The method of claim 1, wherein said doped dielectric layer is selected from the group consisting of fluorine doped silicate glass (FSG), phosphorous doped silicate glass (PSG), boron doped silicate glass (BSG), and boron phosphorous doped silicate glass (BPSG).

~~20~~ 21. The method of claim 2, wherein said metal nitride layer comprises a metal selected from the group consisting of aluminum, tantalum and titanium.

~~21~~ 22. A method for reducing diffusion of dopant ions from a dielectric layer into a metal layer, comprising:

(a) depositing on said metal layer, a nitrogen rich metal nitride layer; and

(b) depositing a layer of doped dielectric material on said nitrogen rich metal nitride layer.

E0089

22. The method of claim 21, wherein said metal nitride layer is made using a radiofrequency (rf) method using at least one variable selected from (a) a hydrogen:nitrogen ratio in the range of about 0.1:1 to about 4:1, (b) an rf power in the range of about 100 Watts per 8 inch wafer to about 1000 Watts per 8 inch diameter wafer, (c) a pressure in the plasma chamber in the range of about 100 milliTorr to about 50 Torr, and (d) a deposition temperature in the range of about 200° C to about 450° C.

23. The method of claim 21, wherein the metal nitride is selected from the group consisting of aluminum nitride, titanium nitride, and tantalum nitride.

24. A method for reducing diffusion of dopant ions from a dielectric layer into a metal layer, comprising:

(a) providing a substrate;

(b) depositing over said substrate, a metal layer from the group consisting of aluminum, titanium, tantalum and aluminum/tantalum;

(c) forming a metal nitride using a nitrogen rich plasma using at least one variable selected from the group consisting of:

(i) a hydrogen:nitrogen ratio in the range of about 0.1:1 to about 4:1;

(ii) an rf power in the range of about 100 Watts per 8 inch wafer to about 1000 Watts per 8 inch diameter wafer;

(iii) a pressure in the plasma chamber in the range of about 100 milliTorr to about 50 Torr; and

a deposition temperature in the range of about 200° C to about 450° C; and

(d) depositing on said metal nitride layer, a layer of doped dielectric material selected from the group consisting of fluorine doped silicate glass (FSG), phosphorous doped silicate glass (PSG), boron doped silicate glass (BSG), and boron phosphorous doped silicate glass (BPSG).

25. A method for decreasing mechanical stress at an interface between two metal layers, comprising:

(a) providing a substrate having a layer of a first metal thereon;

(b) forming, using a nitrogen rich plasma, a layer of first metal nitride on said first metal; and

(c) forming a layer of a second metal on said layer of first metal nitride.

26. A method for forming a semiconductor device, comprising the steps of:

(a) providing a substrate having a layer of pad oxide thereon;

(b) forming a semiconductor stack comprising the steps of forming:

(i) layer of titanium on said layer of pad oxide;

(ii) forming a layer of titanium nitride on said layer of titanium;

(iii) forming a layer of aluminum on said layer of titanium nitride;

(c) etching, in said stack, a trench having sidewalls;

(d) forming a layer of nitrogen rich nitride on said sidewalls; and

(e) filling said trench with a layer of doped dielectric material.

27. A method for forming a semiconductor device, comprising the steps of:

(a) providing a substrate having a layer of pad oxide thereon;

(b) forming a semiconductor stack comprising the steps of forming:

(i) layer of aluminum/tantalum having a ratio of about 50%:50% on said layer of pad oxide;

(ii) forming a layer of titanium nitride on said layer of aluminum/tantalum;

(iii) forming a layer of aluminum on said layer of titanium nitride;

(c) etching, in said stack, a trench having sidewalls;

(d) forming a layer of nitrogen rich nitride on said sidewalls; and

(e) filling said trench with a layer of doped dielectric material.

~~27~~ 29. The method of claim 2, wherein said barrier layer is formed using electromagnetic radiation.

~~28~~ 30. The method of claim 2, wherein said barrier layer is formed using nitrogen ion implantation.

~~29~~ 31. A semiconductor device, comprising:

a gate;

a layer of dielectric material over said gate;

and a metal via through said layer of dielectric material, said via in contact with said gate, said via having a layer of metal nitride separating said via from said layer of dielectric material.

~~30~~ 32. A semiconductor device, comprising:

(a) a substrate having a source region and a drain region formed therein;

(b) a gate, having sidewall spacers, over said substrate and over at least a portion of said source region and said drain region;

(c) layers of silicide over said source region, said drain region and said gate;

(d) a layer of dielectric material over said gate;

(e) a metal via in contact with said gate, said via extending through said layer of dielectric material; and

(f) a layer of metal nitride between said via and said layer of dielectric material.

31. A method for determining the thickness of a layer of a deposited conductive material, comprising the steps of:

(a) selecting at least one deposition condition selected from the group consisting of temperature, reactant concentration, power density, and deposition time;

(b) determining the power law relationship between film thickness and sheet resistance for the deposition condition selected in step (a); and

(c) based on the results of step (b), monitor sheet resistance during deposition until a desired sheet resistance is achieved.

32. The method of claim 31, wherein the power law relationship determined in step (b) is about -1.3.

33. A method for determining the alternations in the surface roughness of the surface of a semiconductor film, comprising the steps of:

(a) directing a beam of electromagnetic radiation at a surface of said semiconductor film;

(b) measuring the scattering of said electromagnetic radiation;

(c) carrying out a process for altering the surface roughness of said film; and

(d) repeating steps (b) and (c) until a desired degree of scattering is achieved.

34. The method of claim 33, wherein step (c) is a process selected from the group consisting of deposition and annealing.

35. The method of claim 33, wherein step (c) is a deposition step.

36. A method for calibrating a semiconductor heating device, comprising the steps of:

(a) depositing onto a semiconductor substrate, a layer of an alloy having a phase transition temperature associated with a change in sheet resistance;

(b) exposing said alloy to a first temperature;

(c) measuring the sheet resistance of said alloy;

(d) exposing said alloy to a temperature different from said first temperature;

(e) repeating step (c); and

(f) repeating steps (d) and (e) until said sheet resistance changes by more than a predetermined value.

39 ~~37~~. The method of claim 36, wherein said alloy is a binary or ternary metal alloy.

40 ~~38~~. The method of claim 36, wherein said alloy is comprised of metals selected from the group consisting of aluminum, copper, germanium and lithium.

41 ~~39~~. The method of claim 36, wherein said alloy is comprised of about 98% aluminum, about 1% copper and about 1% germanium.

42 ~~40~~. The method of claim 36, wherein said alloy is comprised of aluminum and lithium.

41. The method of claim 36, wherein said alloy has a phase transition temperature below about 350° C.

42. The method of claim 36, wherein the thickness of said layer of alloy is in the range of about 100 Å to about 5 µm.

43. The method of claim 36, wherein steps (b) and (d) are carried out in an inert gas.

44. The method of claim 36, wherein steps (b) and (d) are carried out in a gas selected from the group consisting of nitrogen, helium, neon, argon or xenon.

45. The method of claim 36, wherein said heating device is selected from an oven and a rapid thermal processing device.